Geodetic evidence of time-dependent viscoelastic interseismic deformation driven by megathrust locking in the southwest Japan subduction zone

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The time-variable features of interseismic deformation in subduction zones are poorly understood and commonly ignored. Here, by incorporating century-long leveling data and contemporary global navigation satellite systems (GNSS) velocities, we investigate the temporal evolution of interseismic deformation in southwest Japan using two-dimensional viscoelastic earthquake-cycle models. We find that a steady-state continental mantle viscosity of 10^{19} Pa s is required to explain these two geodetic datasets. Model with this preferred viscosity predicts significant variations in the surface velocity field throughout the entire interseismic period due to viscous mantle flow driven by ongoing megathrust locking. This finding indicates that the multiyear GNSS-derived velocity field represents a snapshot of time-varying interseismic deformation. Furthermore, we explore the impacts of locking depth and locking time (the duration of megathrust locking) on surface deformation patterns. We find that the horizontal deformation in the backarc region are sensitive to the locking time due to the ongoing interseismic viscoelastic relaxation, and insensitive to locking depth due to the distance to the plate interface. Vertically, the locking depth controls the trench distance of the peak uplift signal, and the locking time primarily influences the magnitude of the vertical velocities. Taken together, our work highlights the importance of the interseismically relaxing mantle and the necessity of considering such an effect in determining the current locking state along the Nankai subduction zone.

Keywords: leveling and GNSS data, interseismic viscoelastic relaxation, time-dependent deformation, earthquake cycle, Nankai subduction zone, interseismic locking